and the aerobes resume their activity. The aerobes consume the organic matter, use up the oxygen and turn the anaerobes on again, in a continous cycle. Cook says he is not surprised to find an ethylene cycle effecting plant growth, since ethylene regulates many plant processes, including flowering, fruit ripening and the development of some roots.

The cycle is in balance in undisturbed ecosystems such as grassland and forest soils. There, plant nutrients and organic matter are slowly recycled, root diseases are rare and nitrate fertilizers don't accumulate. But in bare, cultivated soil, the cycle is disturbed, and this seems to explain the link between agriculture and soil depletion. Nitrate fertilizer poisons ethylene production, Cook told SCIENCE NEWS, and tilling augments the effects of nitrate on ethylene and destroys the deoxygenated pockets. Organic matter

is therefore broken down more quickly, more nitrogen is released to the atmosphere rather than retained in the soil and the aerobic organisms can proliferate and attack plant roots in greater numbers.

The team is excited by the research, Cook says. It bolsters arguments against the use of nitrate fertilizer (as opposed to ammonium or urea) and full tillage of fields, positions which have been gaining momentum in recent years. It may also lead to the selection of seeds that can be planted in bare, untilled soil and crops that are resistant to the higher ethylene levels in such soil. Ethylene would then act as a natural deterrent to root diseases, and alleviate the need for some chemical agents.

"This research puts the field of microbiology a giant step forward and into the limelight," Cook says, "and may begin to answer a lot of our basic questions about soils and agriculture." □

Relativity for computers: All arithmetic

Three hundred years ago Isaac Newton discovered that to solve the problems of universal gravitation he had set himself he had to invent the branch of mathematics called calculus. Eighty years ago, in formulating special relativity, Einstein caused a revolution in physics by making mass a variable and uniting space and time, but his equations, though changing the content of Newton's, followed Newton's calculus lead. Calculus, in fact dominates classical and most modern physics. For three centuries it has been the physicist's best mathematical friend.

But now the world has digital computers. Digital computers can do calculations with incredible speed. They have prodigious memories. People want to use them wherever a lot of computation must be done in a short time. But computers are not as smart as Newton,

let alone Einstein, or even a college freshman. They can't do calculus. They can only do arithmetic, but they do it very fast.

So a group at the Computer Sciences Department of the University of Wisconsin at Madison under the direction of Donald Greenspan is working out a reformulation of Newton's and Einstein's work, not conceptually, but mathematically, trying to get it on an arithmetic basis so a computer can handle it. They have been successful with Newtonian classical mechanics and fluid dynamics. Greenspan's latest paper (UW's Computer Sciences Technical Report #232) details the first part of a method for special relativity. Later they hope to go to general relativity.

The sticking points in calculus are the concepts of limit and continuity. Limit is a way of getting around Zeno's

paradox, which so bedeviled ancient Greek mathematicians, and showing that an infinite succession of infinitely small steps can in fact lead up to but never surpass a limit that is nevertheless a finite number. Continuity is a property of the sort of equations called functions. A function sets up a relation between an (independent) variable quantity or quantities and another (dependent) variable, so that, knowing the value of the independent variable, one can calculate the dependent one. A function is continuous at a point if an infinitesimal change in the independent variable yields a new finite value for the dependent variable that is only infinitesimally different from the previous one. These two concepts are the keys to the development of integral and differential calculus, and when they had been evolved, 18th-, 19th- and 20th-century physics and engineering were on their way.

What the Wisconsin group has achieved is a way of replacing the infinitesimal steps with finite ones—finite-difference equations— that nevertheless come out to the same thing, in the limit, as the continuous processes of calculus. And it works in practice. "What we do runs," says Greenspan. "Everything we do must go on the computer. Doing it in theory is not enough."

Greenspan says the method should be of wide use to physicists and engineers with all kinds of mechanical, fluid dynamical and special relativistic computations to do. But it is much more than that.

As they were working through the method, the group found, in Greenspan's words, that they were doing physics arithmetically. The conservation laws that define and characterize Newtonian and Einsteinian physics come out of the arithmetic procedure. It is thus not merely a crutch for the computer but an alternate way of deriving and justifying the physically meaningful mathematical statements that have traditionally been gotten by calculus methods. And that could work an important change in high-school curricula.

Calculus—for reasons considered good and sufficient by mathematics teacher—has traditionally been reserved for the first or even second year of college. High-school physics teaching has suffered from the lack. Much of its content had to be brought in on faith or justified by handwaving methods. The new formulation could provide a way of making high-school physics more interesting by deriving its contents in a satisfactory way that the pupils could follow. Greenspan is enthusiastic about the idea of a change, but also extremely realistic. "You have 300 years of vested interest in calculus to overcome," he says. □
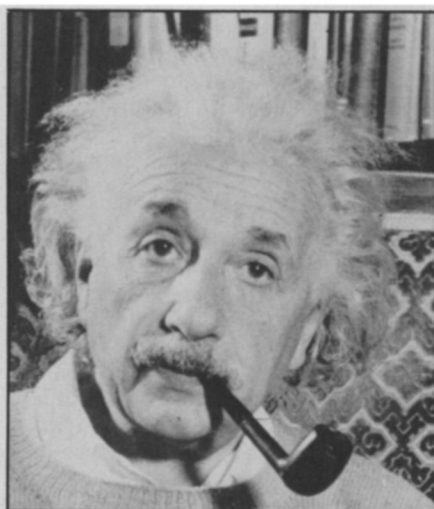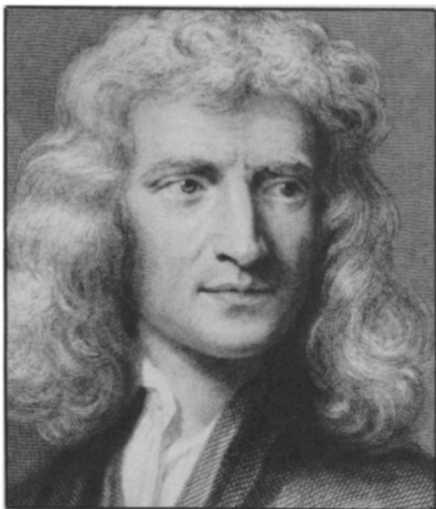
If Newton looks disapproving and Einstein surprised, it may be because the calculus is being calculated out of their theoretical derivations.